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Energy Technology Perspectives 2008

Key Messages

- We are facing an urgent challenge in the energy sector and we need a global solution
- Emissions stabilization – mainly energy efficiency and power sector measures (ACT scenarios)
- Halving emissions by 2050 implies deep cuts for transport and industry (BLUE scenarios)
- Marginal cost ACT USD 50/t; BLUE USD 200/t (optimistic technology estimates)
  - The cost uncertainty increases with ambition level
- USD 45 trillion additional investment needs for BLUE (1% of GDP)
- Important supply security benefits
- We need a step change in government policies, with closer international collaboration
- The roadmaps can provide a focus for this

Key Technology Options (Roadmaps)

- **Supply side**
  - CCS power generation
  - Nuclear III + IV
  - Wind
  - Biomass – IGCC & co-combustion
  - Solar – PV
  - Solar – CSP
  - Coal – IGCC
  - Coal – USCSC
  - 2nd generation biofuels
- **Demand side**
  - Energy efficiency in buildings
  - Heat pumps
  - Solar space and water heating
  - Energy efficiency in transport
  - Electric and plug-in vehicles
  - Fuel cell vehicles
  - CCS in industry
  - Industrial motor systems

Roadmaps

17 technology roadmaps provide 87 % of CO_2 savings under the Blue scenario

- **Potentials**
- **Pathways to commercialization**
- **Technology targets**
- **How to get there**
- **Key actions needed**
- **Key areas for international cooperation**

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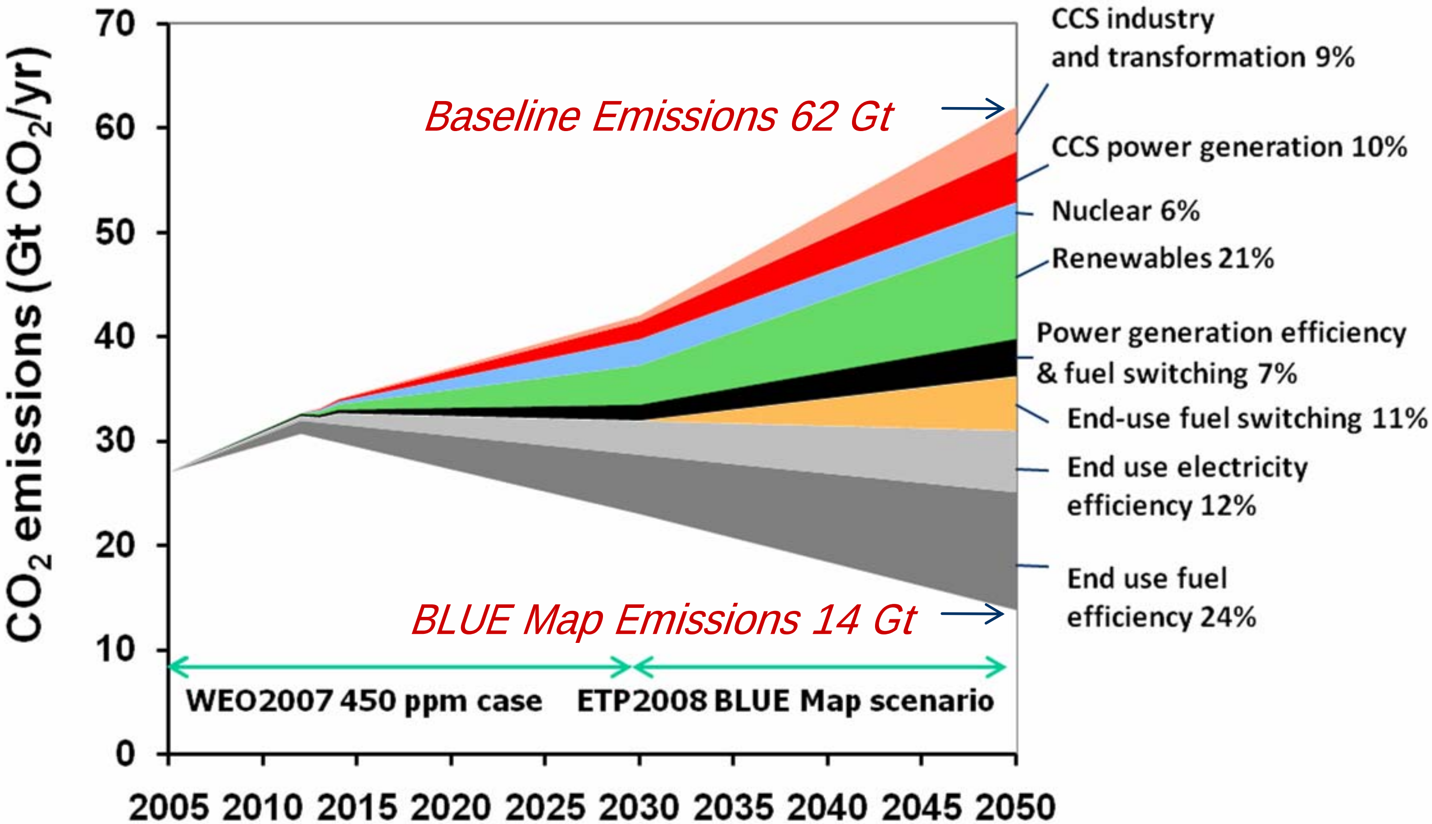
Contribution of Technology Options



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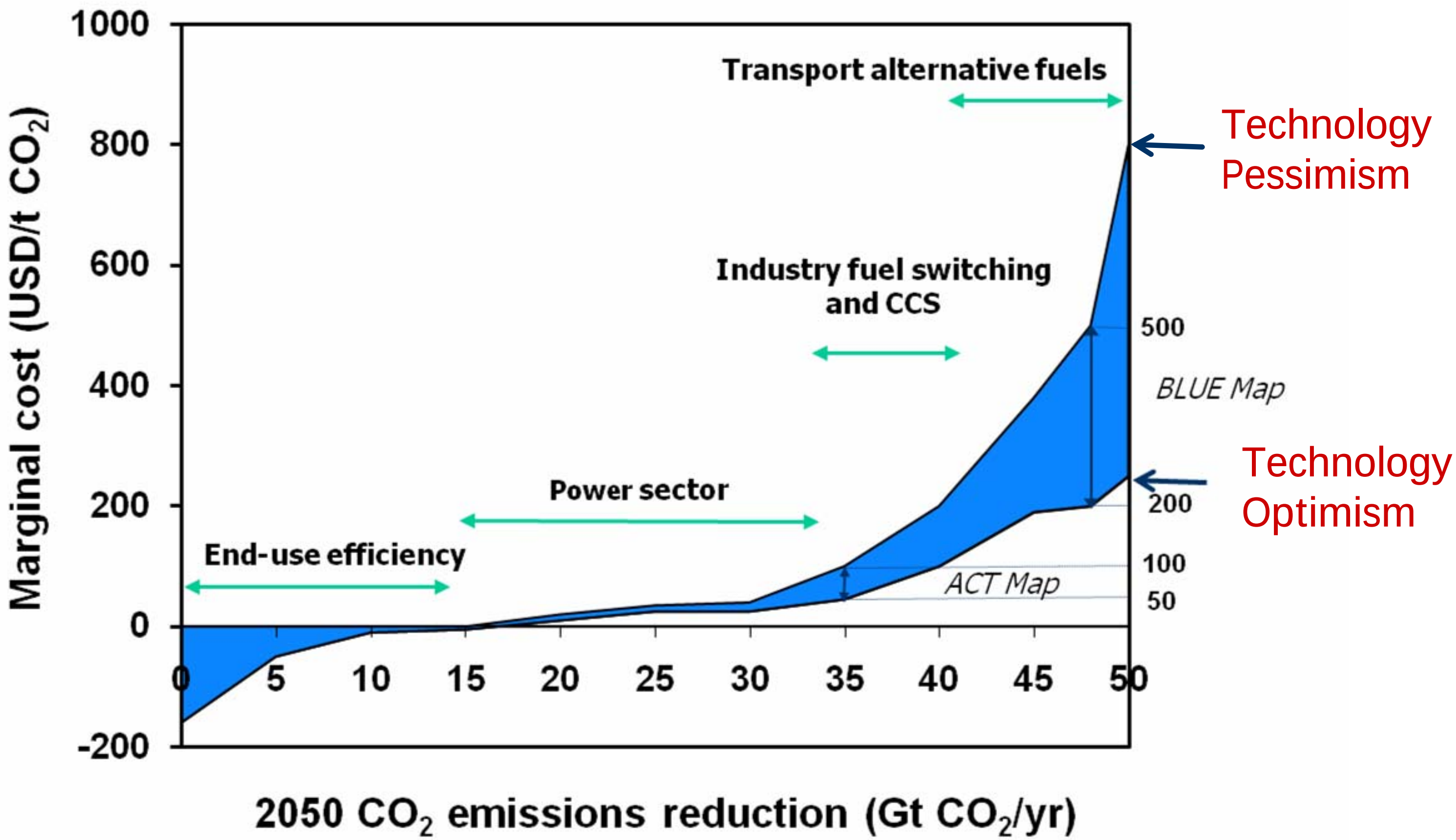
A New Energy Revolution ?



To bring emissions back to current levels by 2050 options with a cost up to USD 50/t are needed. Reducing emissions by 50% would require options with a cost up to USD 200/t, possibly even up to USD 500/t CO2.

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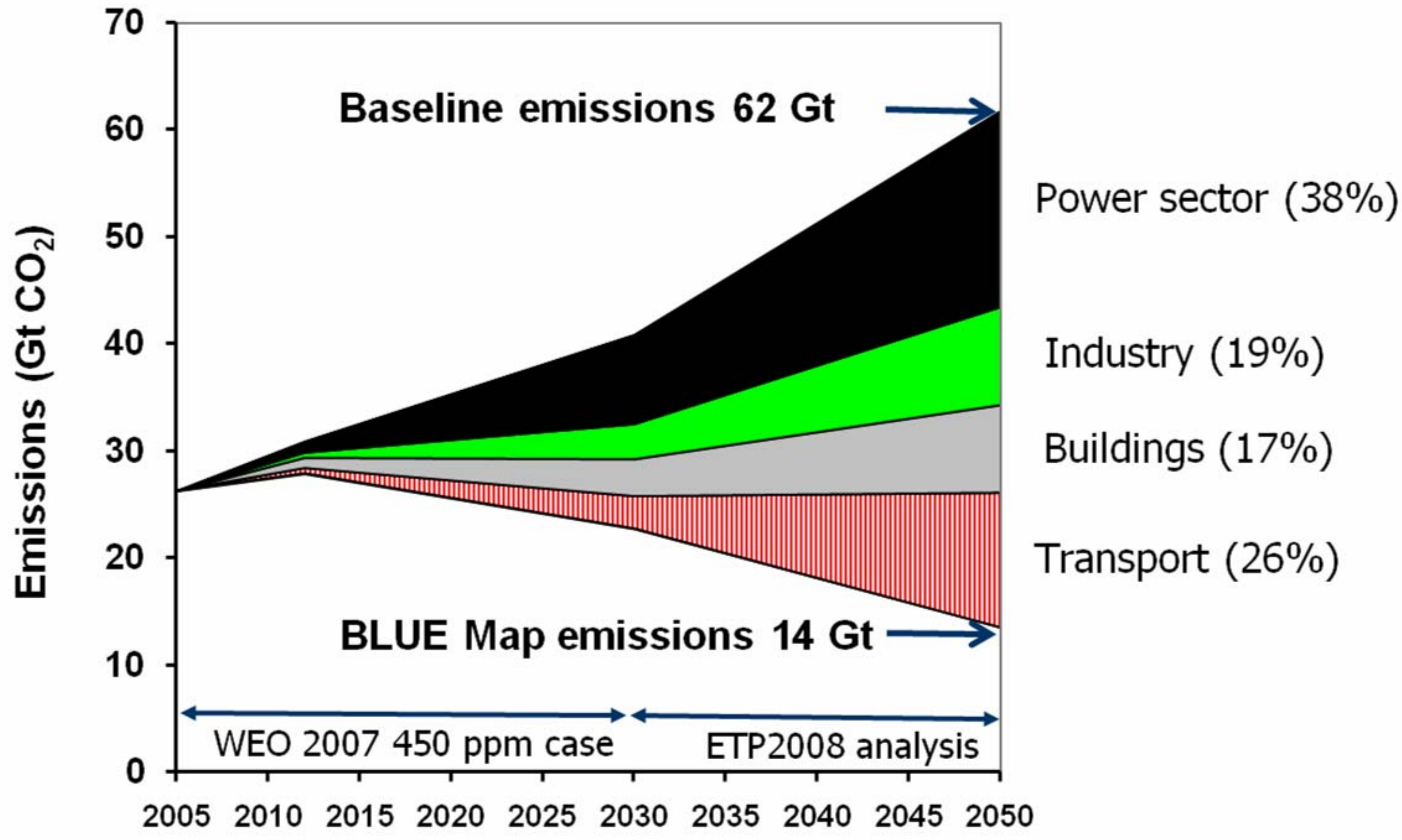
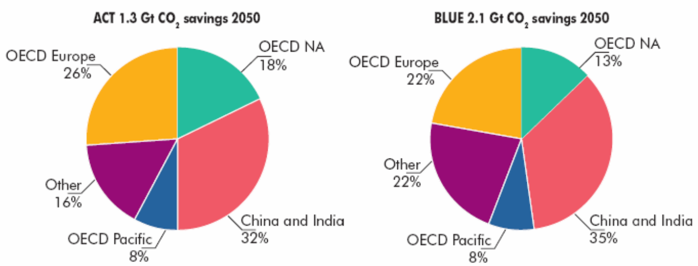
Sector Contributions



Roadmaps – Example Wind Energy

4 % of CO_2 reduction potential in BLUE Map

Onshore and offshore wind energy



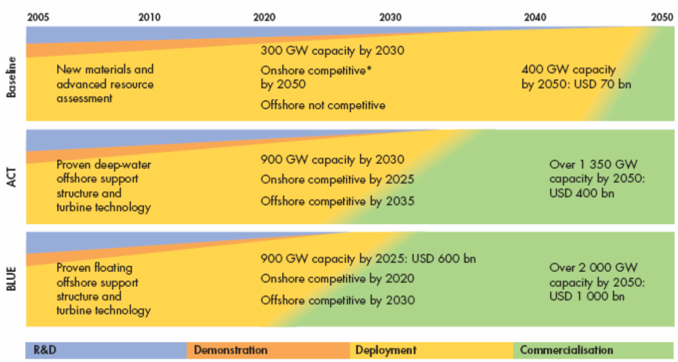
	Global Deployment Share 2030	RDD&D Inv. Cost USD bn 2005-2030	Commercial Inv. Cost USD bn 2030-2050
OECD NA	24%	140-160	75-85
OECD Europe	34%	200-220	100-110
OECD Pacific	10%	60-70	30-35
China & India	25%	150-170	130-140
Other	7%	45-55	65-75

	Global Deployment Share 2025	RDD&D Inv. Cost USD bn 2005-2035	Commercial Inv. Cost USD bn 2035-2050
OECD NA	24%	145-165	130-150
OECD Europe	38%	230-250	210-230
OECD Pacific	10%	60-70	70-80
China & India	19%	110-130	340-360
Other	9%	50-60	215-225

Technology targets

	ACT: Emissions Stabilisation	BLUE: 50% Emissions Reduction
RD&D		
High-resolution global mapping of and long term predictability of wind resource	Meteorological models for predictability. Micro-scale modelling for siting	
Reduce steel dependency	Develop alternative materials	
Reduce O&M "downtime" for offshore turbines	Secure, fast offshore access. Deep offshore support structures and corrosion resistance	Additional tasks as in ACT. Development of floating systems
Investment in RD&D	OECD private and public investment in RD&D should be in the region of USD 300 m per annum	
Deployment		
Available supply of turbines, components and support structures	Larger manufacturing facilities.	
Available transmission capacity. Optimise electricity network	Reinforce weak grids and interconnect. Dynamic line rating, HVDC (offshore)	Additional tasks as in ACT. Grid associated costs are shared across power sector
Maximum wind farm capacity factors	Match power curves to site wind regimes. Worldwide deployment onshore, offshore mainly in OECD	Additional tasks as in ACT. Additional offshore deployment in the developing world

Technology timeline



* Already cost-competitive in good sites, but will take wider deployment to become competitive in general.

Key actions needed

- Internalisation of external costs of all technologies. Presently, the full cost to society of conventional technology is not reflected in price.
- Stable, predictable policy support to encourage investment.
- Fully competitive electricity markets, on a continental scale for aggregation of output from dispersed variable renewable generators, to smoothen aggregate variability profile.
- Reduce lead times for planning and construction of new transmission. In Europe they can be a long as ten years. The needs of large-scale wind power to be considered in the planning of new infrastructure development, onshore and offshore.
- Streamline and accelerate planning for new wind plants.
- Further measures to increase system flexibility (to enable higher share for variable renewables): development and cost reduction of storage technologies, encouragement of dispatchable plant in generation portfolio, interconnection of balancing areas, increased demand-side participation, and shorter scheduling periods (gate closure).
- Low-cost, long-range DC transmissions systems.
- Grid-associated costs are shared across power sector.

Key areas for international collaboration

- International co-operation should focus on identifying and building key interconnectors. Electricity prices vary from country to country, and sometimes regionally. Interconnection will benefit some at the expense of others. Need to find ways to overcome resistance to trade of electricity across borders.
- Offshore interconnection of wind farms.
- Establishment of continental scale, competitive electricity markets.

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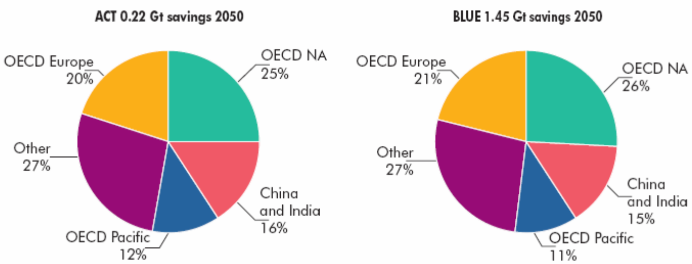
Roadmaps – Example Biomass IGCC
3 % of CO_2 reduction potential in BLUE Map

Biomass integrated gasification combined cycle and co-combustion



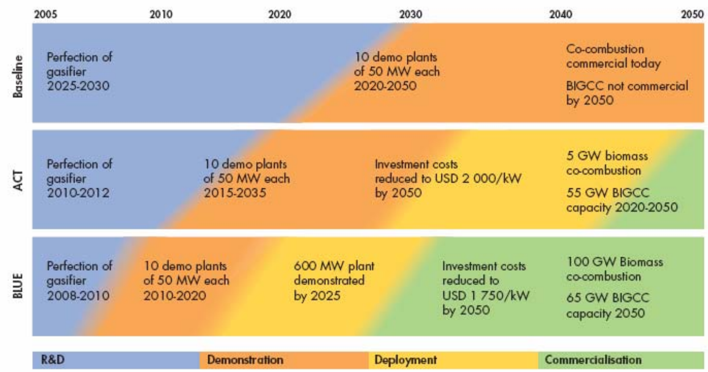
	Global Deployment Share 2050	RDD&D Inv. Cost USD bn 2005-2050	Commercial Inv. Cost USD bn
OECD NA	25%	25-30	n.a.
OECD Europe	20%	20-25	n.a.
OECD Pacific	12%	12-15	n.a.
China & India	16%	15-20	n.a.
Other	27%	25-30	n.a.

	Global Deployment Share 2030	RDD&D Inv. Cost USD bn 2005-2030	Commercial Inv. Cost USD bn 2030-2050
OECD NA	26%	30-35	40-45
OECD Europe	21%	25-30	60-65
OECD Pacific	11%	12-15	15-20
China & India	15%	15-20	20-25
Other	27%	25-30	40-45

Technology targets

	ACT: Emissions Stabilisation	BLUE: 50% Emissions Reduction
RD&D		
Gasification of biomass on a small scale needs to be more reliable and automated, needs continuous feed. RD&D needed for fuel and gas clean up	Plants more reliable by 2012 with gas clean-up mostly solved. Cost reductions from large-scale demo plants. Optimum biomass feed storage, drying and handling systems	Multi-fuel bio-refineries including BIGCC as part of the process need RD&D (USD 900 m). Biomass fuel standardised. Technology transfer to developing countries
Oxygen and air-blown plants demonstrated	Oxygen vs. air-blown benefits understood, but expensive vs. standard steam cycle systems	
Develop coal plants that can accommodate higher biomass shares	Maximise co-combustion.	
Develop co-gasification for NGCC	By 2020	By 2015
Deployment		
Efficient, reliable gasifiers with low air emissions need demonstration to gain additional learning experience	Early commercial BIGCC plants operating by 2015	Growth rate of 25%/yr after 2015 declining to 3-5% by 2040 as biomass becomes constrained. 1-2 plants built on avg. / month from 2020 to 2050

Technology timeline



Timeline reflects Biomass Integrated Gasification Combined Cycle. Co-combustion technologies already commercial today.

Key actions needed

- Biomass resources need to be identified and secured for the long term by plant developers. Optimum plant locations identified by GIS process with transport infrastructure optimised.
- Co-combustion of biomass in coal-fired power plants should be encouraged.
- Reliability of gasifiers, especially the challenging gas clean-up process, needs demonstrating over the long term to give confidence to potential investors. Various biomass types, including black liquor and bagasse, should be considered.
- Gasifier development can be run in parallel with synthetic biofuels produced using the FT process and methanol/DME. Industry investment a key for success, building on knowledge of earlier plants.
- Technology transfer including data on fuel specifications and suitability needed for uptake in developing countries where local manufacture is encouraged.
- Full life-cycle analyses to be undertaken to ensure a sustainable system results.
- Once CCS has become fully commercial for coal plants, it can be tested for integration with BIGCC systems. First BIGCC plants with CCS in 2030 (BLUE).

Key areas for international collaboration

- A review of successes and failures of biomass gasification plants to date, to identify problems.
- Joint funding of large-scale plants in developing countries by industry and governments.
- International standards on fuel quality, air emissions and plant designs needed.
- Technology transfer for small- and large-scale plants undertaken collaboratively.

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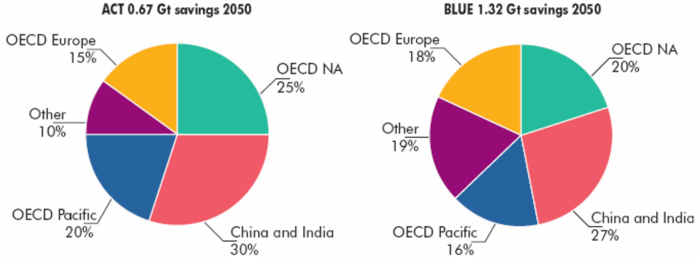
Roadmaps – Example PV systems
3 % of CO_2 reduction potential in BLUE Map

Photovoltaic systems



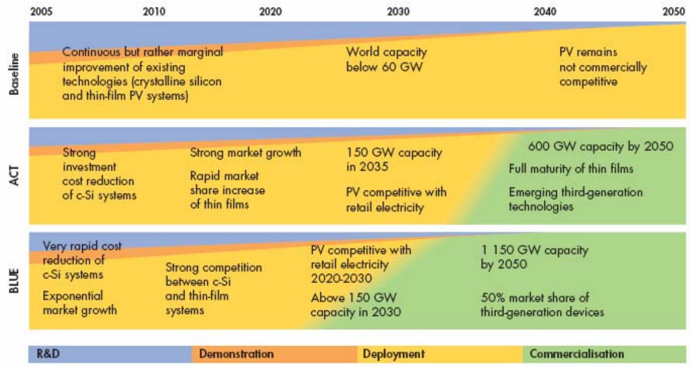
	Global Deployment Share 2035	RDD&D Inv. Cost USD bn 2005-2035	Commercial Inv. Cost USD bn 2035-2050
OECD NA	25%	45-55	120-130
OECD Europe	25%	45-55	75-85
OECD Pacific	30%	55-65	100-110
China & India	15%	25-35	150-160
Other	5%	10-12	50-55

	Global Deployment Share 2030	RDD&D Inv. Cost USD bn 2005-2030	Commercial Inv. Cost USD bn 2030-2050
OECD NA	25%	45-55	200-220
OECD Europe	25%	45-55	180-190
OECD Pacific	25%	45-55	250-260
China & India	20%	40-45	270-280
Other	5%	10-12	180-190

Technology targets

	ACT: Emissions Stabilisation	BLUE: 50% Emissions Reduction
RD&D		
Increase efficiency and reduce material intensity and costs of c-Si modules	c-Si module efficiencies above 20%. Cost-effective and alternative silicon feedstock supply developed	c-Si modules efficiency around 25%
Increase efficiency and lifetime of thin films	Thin film module performances15-18%, lifetime of 25-30 years	Thin film modules reach efficiencies of 20-25%, lifetimes of 30-35 years
Develop 2 types of 3rd generation devices: • Ultra-high efficiency cells • Ultra-low cost cells • Low-cost building integration	Third-generation technologies un-derstood, demonstration plants in niche market applications	Third-generation devices fully deve-loped and deployed: • Devices above 40% efficiency • Ultra-low-cost cells reach 10-15% efficiencies, lifetimes of 10-15 years
Deployment		
Building integration and storage	Fully integrated and multi-functional PV applications in buildings. Use of advanced storage facilities	
Cost target	Investment costs reduced to USD 2.2/W in 2030, 1.2/W by 2050	Investment costs reach USD 1.9/W in 2030 and USD 1.1/W by 2050

Technology timeline



Key actions needed

- Double technology shift: from crystalline silicon (c-Si) to thin films, to third-generation novel devices.
- Sustained and effective incentives needed in the next 5-10 years to overcome the pre-competitive stage of PV systems.
- Guarantee long-term high purity silicon feedstock supply, develop alternative feedstock production routes.
- Guarantee sufficient public and private R&D funding for the development of third-generation novel devices (ultra-high efficiency and ultra-low-cost cells).
- Up-scaling of manufacturing capacity to the 1-10 GW/year scale per manufacturing plant.
- Develop standardised solutions for building integration in collaboration with the construction industry.
- Address technology transfer issues for application in developing countries, with specific respect to off-grid applications.

Key areas for international collaboration

- Development and application of international standards in measuring PV module and system performances under real and large-scale application conditions.
- Technological spill-over from other industry sectors (e.g. thin film and LCD screen production).
- Pre-competitive R&D collaboration in the field of 3rd generation devices: nanotechnologies, concentrators, dye-sensitised cells, organic cells.
- Management of end-of-life recycling of modules.
- Technology transfer for small & large-scale plants undertaken collaboratively.

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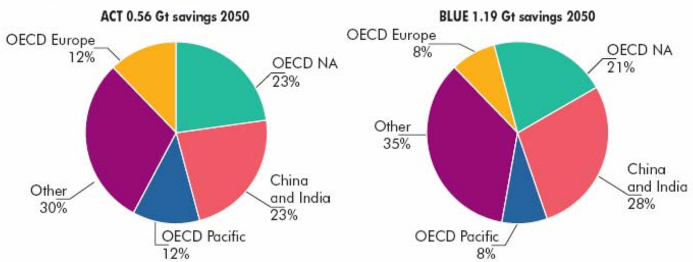
Roadmaps – Example CSP
3 % of CO_2 reduction potential in BLUE Map

Concentrating solar power



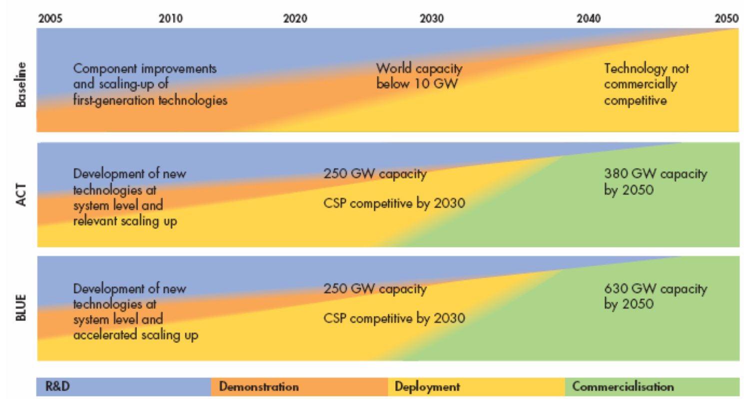
ACT	Global Deployment Share 2030	RDD&D Inv. Cost USD bn 2005-2030	Commercial Inv. Cost USD bn 2030-2050
OECD NA	25%	65-75	45-50
OECD Europe	15%	40-50	25-30
OECD Pacific	15%	40-50	25-30
China & India	25%	65-75	45-50
Other	20%	55-65	50-55

BLUE	Global Deployment Share 2030	RDD&D Inv. Cost USD bn 2005-2030	Commercial Inv. Cost USD bn 2030-2050
OECD NA	23%	60-70	60-70
OECD Europe	14%	35-40	25-30
OECD Pacific	14%	35-40	25-30
China & India	24%	65-75	80-90
Other	25%	65-75	100-110

Technology targets

	ACT: Emissions Stabilisation	BLUE: 50% Emissions Reduction
RD&D		
System efficiency	Increase efficiency of systems to reduce costs	
Trough plants	Development of direct steam generation for trough plants	
Development of new technologies at system level for trough, dishes and towers	• Towers with air receivers to significantly increase working temperatures and conversion rates, demo by 2012 • Combined power and desalination plants, demo by 2012	Solar production of hydrogen and other energy carriers, demo by 2020
Low-cost, high efficiency thermal storage	Storage costs to fall to USD 0.05/kWh and efficiencies greater than 95%	
Deployment		
• Cogeneration power desalination • Troughs + direct steam generation • Troughs + molten salts	Commercial deployment by 2020	
Towers + air receiver + gas turbine	Commercial deployment by 2030	

Technology timeline



Key actions needed

- Economies of scale, mass production, learning by doing, and incremental improvements of all system components (mirrors, infrastructures, sun-tracking, heat receivers, pipes, balance of plants, etc.) will combine to improve performances and reduce costs.
- The emergence of heat storage, as an alternative to back-up with fossil fuels, significantly increases the value of the electricity produced in making power capacities guaranteed or even dispatchable.
- The development of incremental improvements such as direct steam generation, use of molten salts in troughs, cogeneration of heat for desalination and power, and cheaper dishes will further help increase performance and reduce costs.
- Development of towers with air receivers will significantly increase working temperatures and conversion rates and reduce costs even further, but still requires important R&D efforts.
- Low-cost long-range DC transmission systems.

Key areas for international collaboration

- Continuing co-ordination of R&D efforts, outreach efforts sharing and information exchanges through IEA's SolarPACES Implementing Agreement.
- Effective financing of CSP plants in developing countries beyond the global environment facility-supported plants.
- Developing efficient interconnection via high-voltage, direct-current lines to feed important consuming areas from neighbouring sunny regions.

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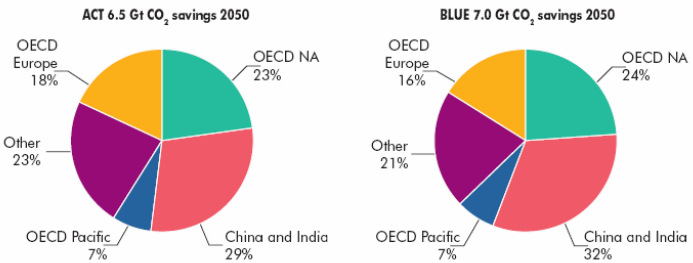
Roadmaps – Example Efficiency Buildings and Appliances

15 % of CO_2 reduction potential in BLUE Map

Energy efficiency in buildings and appliances



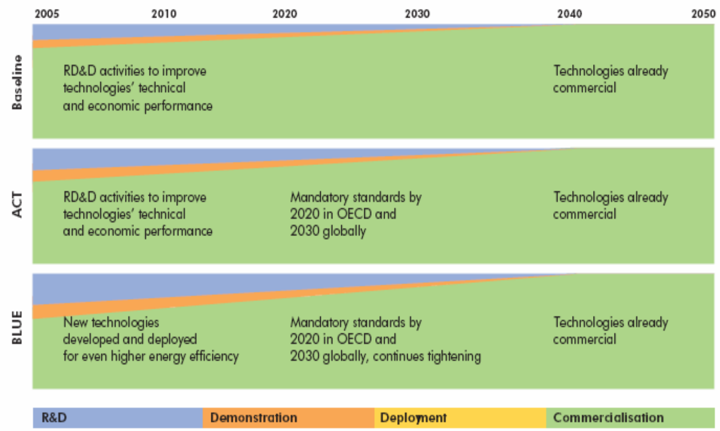
ACT	Commercial Inv. Cost USD bn 2005-2050
OECD NA	1 100-1 200
OECD Europe	850-950
OECD Pacific	300-400
China & India	1 000-1 200
Other	1 800-2 000

BLUE	Commercial Inv. Cost USD bn 2005-2050
OECD NA	1 500-1 700
OECD Europe	950-1050
OECD Pacific	450-550
China & India	1 500-1 800
Other	2 200-2 500

Technology targets

	ACT: Emissions Stabilisation	BLUE: 50% Emissions Reduction
Diffusion		
Limit standby power use to 1-Watt.	Implemented in OECD countries between now and 2030; and globally by 2040	Implemented in OECD countries between now and 2020; and globally by 2030
Tighten or establish minimum energy efficiency standards for all major existing appliances	New appliances standards shifted to LLCC between now and 2020 in OECD and by 2030 globally	New appliance standards shifted to BAT between now and 2020 in OECD and globally by 2030.
Mandatory standards across full range of mass-produced equipment	Appliances brought under standards by 2030 in OECD and by 2040 globally	Standards for appliances by 2020 in OECD and 2030 globally. Continuous tightening required
Building codes	Cold countries at "low-energy" standard from 2015 and globally from 2030	Cold countries to meet "passive house" levels by 2015, and globally from 2030
Adopt best practice in lighting efficiency	Policy must shift to LLCC from 2015	Policy must begin shift to BAT from 2025 onwords
Promote low-energy houses and fuel switching	Simplified planning requirements to encourage low-energy buildings and alternative fuel sources (especially solar)	

Technology timeline



Key actions needed

- Monitor energy efficiency improvements in existing buildings and appliances. Need to collect consistent and comprehensive data on end-use consumption and energy efficiency worldwide.
- Implementation of mandatory minimum efficiency performance standards (MEPS), harmonised at a high level of efficiency and implemented worldwide, ongoing tightening will be required.
- International standards need to be reviewed regularly to ensure adequate vigor.

Key areas for international collaboration

- Establish a common set of efficiency "tiers" from which countries could draw when they establish minimum energy performance standards.
- Facilitate the rapid exchange of BAT in the buildings sector to ensure rapid uptake worldwide.
- Promote the diffusion of passive house design, construction techniques and energy technologies.

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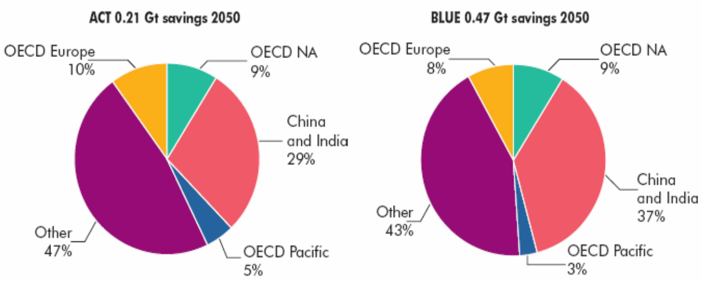
Roadmaps – Example Solar Heating
1 % of CO_2 reduction potential in BLUE Map

Solar space and water heating



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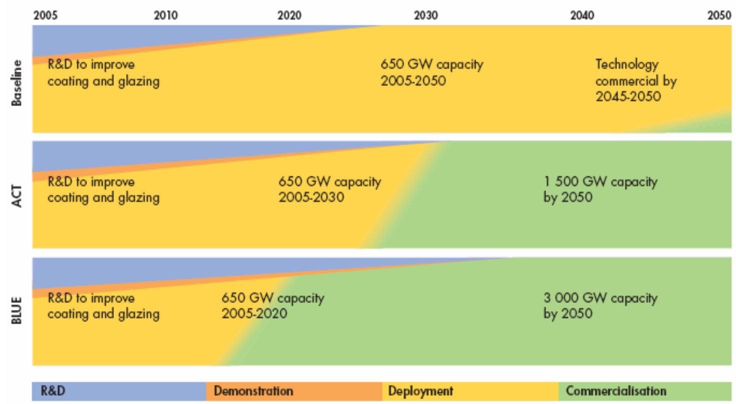
OECD NA	20%	50-55	30-35
OECD Europe	20%	50-55	30-35
OECD Pacific	15%	40-45	15-20
China & India	20%	50-55	90-100
Other	25%	65-70	140-150

	Global Deployment Share 2020	RDD&D Inv. Cost USD bn 2005-2020	Commercial Inv. Cost USD bn 2020-2050
OECD NA	20%	50-55	55-65
OECD Europe	20%	50-55	50-60
OECD Pacific	15%	40-45	20-25
China & India	20%	50-55	240-250
Other	25%	65-70	280-290

Technology targets

	ACT: Emissions Stabilisation	BLUE: 50% Emissions Reduction
RD&D		
Improve heat storage systems	Develop cheap, simple solar-assisted heating devices for mass production	District CHP schemes using combinations of solar/biomass/geothermal widely deployed
Deployment		
Affordable ownership to empower user choice	Policies to encourage widespread deployment to reduce costs with mass production	
Mandate for integrated renewable technologies	Combi solar thermal/cooling PV systems in place. Concentrating solar heat used by industry incorporating heat storage and bioenergy systems	
Utility related	Finance schemes by utilities to save grid upgrades	

Technology timeline



Key actions needed

- Solar heating technologies are already deployed but currently tend to be high-cost options in cold climates. RD&D is needed to help drive down unit costs and improve efficiency. This is particularly the case for solar thermal.
- Need for priority actions on policy development to ensure all new buildings are designed to need minimal heating over their lifetimes, this will help facilitate solar thermal. Retrofits are also to be encouraged where feasible. Capacity building, continued education of architects and builders is required.
- Ownership of small-scale systems is key for both industry and domestic sectors. Distributed systems, however, need micro-financing. There is an opportunity for utilities to look for new business, i.e. by leasing technologies, and to avoid costly grid upgrades as demand increases.
- The connection between energy-efficiency and supply is key for solar heating systems. Metering systems are needed to encourage awareness and provide better data for policy-making and planning.

Key areas for international collaboration

- Policy development for heating has been neglected, so opportunity exists to develop jointly.
- Joint RD&D with industry is encouraged to gain more rapid development.
- Heat metering, micro-finance schemes and capacity building of installers are areas to be addressed.

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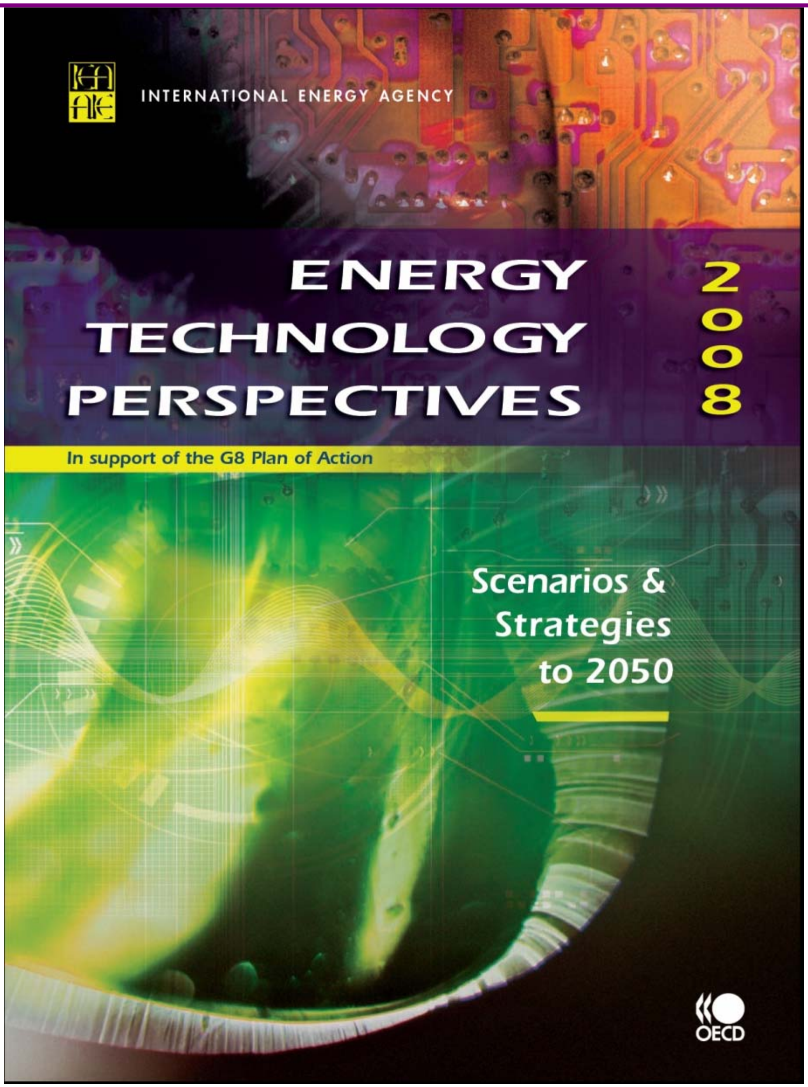
Thank You !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